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Seasonal Dust Accumulation on Commonly Growing Sub-Temperate Vegetation along National Highway

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ABSTRACT

Atmospheric particulate matter is a mixture of diverse elements which are emitted out of motor vehicles. These affect the overall growth and development of plants according to their physical and chemical nature and are one of the major culprits for stress induced changes in plants. Surface dust deposit may alter the optical properties of leaves, particularly the surface reflectance in the visible and short wave infra-red radiation range. Dust capturing capacity of plants depends on the surface geometry, phyllotaxy and characteristics such as hair, cuticle, height and canopy of plant as well as on the properties of particles. In the present study dust interception efficiency of some selected plant species alongside the National Highway 5 from Solan to Shimla in Himachal Pradesh was assessed. Three commonly grown plant species along the National Highway viz. *Quercus leucotrichophora, Debregeasia saeneb and Rubus ellipticus* were selected for the study. Maximum dust was found to be accumulated in case of *Debregeasia saeneb* (0.078 gm^{-2}) during the summer season while least was observed in case of Quercus *leucotrichophora* (0.023 gm^{-2}) during the monsoon season. Maximum dust accumulation was recorded in case of *Debregeasia saeneb* at distance (0-5 m) from the National Highway while least was observed in case of *Quercus leucotrichophora species* at the distance >100 m from the National Highway. Both *Debregeasia saeneb and Rubus ellipticus* shrubs can be recommended for plantation as they can serve as a buffer by accumulating large amount of dust.

Key words:

Debregeasia saeneb, dust accumulation, *Quercus leucotrichophora*, Pollution, *Rubus ellipticus*

INTRODUCTION

Atmospheric particulate matter (PM) is a mixture of diverse elements and the PM with aerodynamic diameter < 10 μm diameter (PM 10) or < 2.5 μm diameter (PM 2.5) is of most concern in context of public health due to presence of PAHs (Polycyclic Aromatic Hydrocarbons) (NEPC 1998, 2003). The major sources of dust pollution include vehicular exhausts, thermal power plants, cement industries, construction activities, brick kilns, open waste burning, agriculture related activities such as biomass burning etc. (Gupta et al. 2016, Karanasiou et al. 2014; Upadhyay et al. 2015). Removal of pollutants by plants from the air is

done by three means, namely absorption by the leaves, deposition of particulates and aerosols over the leaf surface, and fallout of particulates on the leeward side of vegetation which is mainly influenced by air movement (Rawat and Banerjee 1996). Air particulates affect the overall growth and development of plants according to their physical and chemical nature (Gupta and Ghouse 1987). Limestone and cement dusts, with pH values of 9 or more may lead to direct injury to leaf tissues (Vardak et al. 1995) or may cause indirect injury through soil pH alteration (Hope et al., 1991; Auerbach et al. 1997). Suspended particulate matter usually clogs stomata apertures thereby preventing the exchange of gases by leaves Panwar and Bhardwaj (2005). The film of dust causes a hazardous situation for plants as it causes a reduction of effective pollination (Anonymous 1983).

The capacity of tree species to intercept dust depends on its surface geometry, phyllotaxy, leaf external characteristics (such as hairs, cuticles etc.) and height (Nowak 1994 and Singh 2000). Properties of both particles and the vegetation are important in deciding the effectiveness of particle removal from the atmosphere (Prajapati 2012). Leaves have differences in several aspects of their surfaces as some types of leaves have greater surface rigidity or roughness than others, which may influence their stickiness or particle solubility. The leaves with complex shapes and large circumference area collect particles more efficiently when compared to simple leaves with smaller area (Ingold 1971). Certain plant leaves may be more useful for efficient dust capturing than other plants (Anonymous, 2006). Many trees like Neem *(Azadirachta indica)*, Silk cotton *(Bombax ceiba)*, Indian laburnum *(Cassia fistula)*, Gulmohar *(Delonix regia)*, Pipal *(Ficus religiosa)*, Jacaranda *(Jacaranda mimosifolia)*, Indian lilac *(Lagerstroemia indica)*, Temple tree *(Plumeria rubra)*, Java plum *(Syzygium cumini)* and several other roadside trees have been found to be suitable for dust accumulation in urban environment.

Himachal Pradesh is one of the beautiful Indian states owing to its lush green valleys and beautiful meadows. It witnesses throngs of people from all over the world. Tourism and horticulture are lifelines of the state which influence the number of automobiles entering the capital. Solan-Shimla highway is one of the busiest highways of the state and therefore, was chosen for the present study. Further, a plant's response may alter under varying pollution stress; however, until now, no study has been done in ecologically sensitive hilly regions of this stretch of Solan-Shimla highway to determine the amount of dust accumulation by roadside plant species. The plant species which accumulate maximum amount of dust can be suggested for plantation along the highway to act as a filter for air pollutants emanating from increased traffic flow to the state. This study is also important because no extensive research has been carried out in temperate zones of the country.

MATERIALS AND METHODS

Study area

The study was conducted along the stretch of National Highway from Solan to Shimla covering a distance of 45 Kilometres. The stretch of this highway where study was conducted is situated at an altitude of 1480-1870 metres above mean sea level. The average annual rainfall of the study area is around 1150-1600 mm and the average temperature varies from around 10°C in winters to 32°C in summers. The terrain in the area is hilly with steep slopes having shallow, gravely and light textured soils with low water retentivity. The area is fragile and is prone to soil erosion.

Plant species

Three commonly grown plant species viz. *Debregeasia saeneb*, *Rubus ellipticus* and *Quercus leucotrichophora* were selected for the study. These species are the most commonly found plant species along the National Highway and are present throughout the year.

Data collection

The study was conducted during 2013-15 and data was collected in all four seasons (winter, spring, summer and monsoon). In order to study the horizontal distribution of the dust content, distances like 0-5 m, 5-10 m and >100m were considered. The entire stretch of National Highway was divided into three sections of 15 Km each and

three composite samples (10 leaves per sample) of each species were collected from each section. The present work was carried out at Himalayan Forest Research Institute (HFRI), Panthaghati, Shima (Himachal Pradesh) and Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh).

Leaf dust accumulation

The upper surface of leaves was cleaned with a fine brush and identification mark was put. All the leaves were left as such for dust accumulation and after 24 hours, the dust was collected on pre-weighed butter paper bags. After estimating the amount of dust accumulated, the leaves were cut from petiole and were kept in an ice box and brought to the laboratory for analysis (Singh, 2012). The amount of dust accumulated on the leaves was calculated from the equation:

$$W = \frac{W_2 - W_1}{A}$$

W is the dust content ($g\,m^{-2}$)

W1 is the initial weight of the butter paper bag (g)

W2 is the final weight of the butter paper bag (g)

A is the area of leaf (m^2)

Statistical analysis

Effect of species, distance and season on dust deposition was analyzed using factorial ANOVA and when significant differences were observed, pair wise comparisons were carried out between different effects using Bonferroni multiple comparison statistic. All statistical analysis was performed using statistical software Statistica version 7 (Statistics USA).

RESULTS AND DISCUSSION

Species effect on dust accumulation

Dust content was found to be significantly different in all the three species at 5% level of significance. Maximum dust content was found to be accumulated by Debregeasia saeneb (0.060 gm^{-2}) followed by Rubus ellipticus (0.055 gm^{-2}) and Quercus leucotrichophora (0.041 gm^{-2}) (Table 1) irrespective of the season. Higher amount of dust accumulation by *Debregeasia saeneb* and *Rubus ellipticus* may be attributed to the fact that both these species have rough leaf surfaces, while *Quercus leucotrichophora* is found to have a smooth leaf surface and waxy coating. Moreover, *Debregeasia saeneb* has a large leaf surface area. These findings are in conformity with the results of Singh (2012) and Vora and Bhatnagar (1986). Garg et al. (2000) have also reported dust accumulation as per leaf characteristics of plants. Rai and Panda (2014) opined that plants with waxy coating, rough surface with folded margin accumulate more dust than plants with smooth, flat surface without folded margin. The capacity of plants to deposit dust depends on their surface geometry, phyllotaxy and leaf external characteristics such as presence/absence of hairs, cuticle, length of petiole, height and canopy (Sharma and Butler 1975; Sharma 1992; Thakur and Mishra 2010). The dust interception capacity of plants is also influenced by weather conditions, direction and speed of wind (Rai and Panda 2014). Joshi and Bora (2011) also observed that changes in the amount of dust accumulated by different species were influenced by leaf characteristics as Psidium guajava accumulated maximum dust content due to its slightly folded margins, waxy coating, rough surface and small petioles that reduce the movement of leaves in the wind.

Table 1. Species-wise variation in dust accumulation of commonly growing species along the National Highway five

Species	Dust accumulation (gm^{-2})
Quercus leucotrichophora	$0.041^{a} \pm 0.013$
Rubus ellipticus	$0.055^{b} \pm 0.020$
Debregeasia saeneb	$0.060^{c} \pm 0.032$

Mean having same superscript are not significantly different ($p<0.05$)

Season effect on dust accumulation

Maximum dust content accumulation was observed in summer season followed by spring and winter seasons while the minimum dust accumulation was observed in monsoon season.

Distance effect on dust accumulation

The highest amount of dust accumulation was recorded at distance 0-5 m from the National Highway followed by 5-10 m and the least dust accumulation was recorded for species found at distance > 100 m from the Highway.

Species × season interaction effect on dust accumulation

The interaction effect of species × season was found to be significant ($p<0.05$) on dust accumulation and lower dust content was observed in all the three species during monsoon season. Maximum dust was found to be accumulated in case of Debregeasia saeneb species (0.078 g/m^{-2}) during the summer season while least was observed in case of *Quercus leucotrichophora* species (0.023 gm^{-2}) during the monsoon season (Table 2). Prajapati and Tripathi (2008) and Singh (2012) also observed that the least amount of dust was found to be accumulated during the monsoon season. Prusty et al. (2003) also revealed that dust accumulation varied in vegetation with seasons. This could be because of washout effect of rain during monsoon season which results in low dust deposition. Gupta et al. (2016) also observed that dust accumulation was lowest during monsoon season due to scavenging of particulate matter by rain. Rai and Panda (2014) observed that dust accumulation efficiency was highest in winter followed by summer and lowest in rainy season. The effect of species on dust accumulation during monsoon season was not found to be significant, while *Debregeasia saeneb* and *Rubus ellipticus* were found to accumulate higher dust amount in other seasons when compared to *Quercus leucotrichophora*.

Table 2. Seasonal variation in dust accumulation of species growing along the National Highway five

Species	Season	Dust (gm^{-2})	
		Means	SE
Quercus leucotrichophora	winter	0.047^{c}	0.003
	spring	0.044^{c}	0.002
	summer	0.050^{c}	0.002
	monsoon	0.023^{b}	0.001
Rubus ellipticus	winter	0.063^{a}	0.003
	spring	0.063^{a}	0.003
	summer	0.066^{a}	0.003
	monsoon	0.027^{b}	0.001
Debregeasia saeneb	winter	0.065^{a}	0.004
	spring	0.071^{a}	0.004
	summer	0.078^{d}	0.004
	monsoon	0.029^{b}	0.004

Mean having same superscript are not significantly different ($p<0.05$)

Species×distance interaction effect on dust accumulation

Species×distance interaction was also found to be significant on dust accumulation at 5% level of significance. Dust content was found to decrease significantly ($p<0.05$) with an increase in distance from the National Highway in all the three species. Maximum dust was found to be accumulated in case of *Debregeasia saeneb* (0.079 gm^{-2}) at distance of 0-5 m from the National Highway while least was observed in case of *Quercus leucotrichophora* (0.023 gm^{-2}) at the distance >100 m from the National Highway (Table 3). The findings are in line with Walker and Everett (1987) who studied road dust and its environmental impact on Alaskan Taiga and tundra and reported that there is decrease in dust load on leaves with increasing distance from the National Highway. Spatt and Miller (1981) also reported that dust arising from vehicular traffic settled in greatest quantities near the road and the amount decreases with an increase in distance from the road. Singh (2012) also noticed a similar trend in vegetation growing on National Highway 5 from Parwanoo to Solan.

Table 3. Status of dust accumulation of species growing at different distances along the National Highway five

Species	D	Dust (gm^{-2})		
		Mean		SE
Quercus leucotrichophora	> 100 m	0.023	d	0.001
	(0 – 5) m	0.052	b	0.002
	(5 – 10) m	0.048	b	0.002
Rubus ellipticus	> 100 m	0.033	a	0.001
	(0 – 5) m	0.071	c	0.003
	(5 – 10) m	0.062	e	0.002
Debregeasia saeneb	> 100 m	0.033	a	0.002
	(0 – 5) m	0.079	f	0.004
	(5 – 10) m	0.069	c	0.004

Mean having same superscript are not significantly different ($p<0.05$)

Investigations related to quantification of the dust capturing capacity of urban canopies have received attention in the recent past decades (Ram et al. 2015). The estimations of removal of atmospheric particulate matter by plants have been done by several researchers. Maheshwari (1963), Chee and Ridwan (1984) and Shetye and Chaphekar (1980) surveyed the dust fall on common roadside trees in Mumbai (India) and reported that the leaves of Mango *(Mangifera indica)*, Ashoka *(Polyalthia longifolia)*, Pongamia *(Derris indica)* and Umbrella *(Thespepsia populnea)* trees captured higher amounts of dust as compared to other neighbouring plants. Filtering capacity of greenbelts increases with more leaf area, and is reported higher for trees than bushes or grassland (Givoni, 1991). Wang et al. (2011) investigated the leaf dust capturing capacities of 14 common urban greening plants and their relationships with surface micro morphology and found that among the selected plant species, leaf dust capturing capacities ranged from 0.23 gm^{-2} *(Trifolium repens)* to 4.51 gm^{-2} *(Pittosporum tobira)*.

CONCLUSION

Dust content was found to be significantly different in all the three species. Maximum dust

content was found to be accumulated by *Debregeasia saeneb* followed by *Rubus ellipticus* and *Quercus leucotrichophora*. Dust content was found vary significantly in all the three species at different seasons and distance from the National Highway. Irrespective of the species, maximum dust content accumulation was observed in summer season followed by spring and winter seasons while the minimum dust accumulation was observed in monsoon season. The highest amount of dust accumulation was recorded at distance 0-5 m from the National Highway followed by 5-10 m and the least dust accumulation was recorded for species found at distance > 100 m from the Highway. Dust content was found to be significantly lower in all the three species during monsoon season. Maximum dust was found to be accumulated in case of *Debregeasia saeneb* species during the summer season while least was observed in case of *Quercus leucotrichophora* species during the monsoon season. Maximum dust was found to be accumulated in case of *Debregeasia saeneb* at distance (0-5 m) from the National Highway while least was observed in case of *Quercus leucotrichophora* at the distance >100 m from the National Highway. *Debregeasia saeneb* and *Rubus ellipticus* shrubs can be recommended for plantation as they can serve as a buffer by accumulating large amount of dust owing to their high dust capturing ability.

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